

Site 300

Keeps High-Explosives Science on Target

Explosions and nondestructive tests at Site 300 assure that the nation's HE and other nonnuclear weapon components are safe and reliable.

YOU might hear a loud BOOM occasionally, but little else indicates what goes on there. Tucked away in the rugged, grassy hills between Livermore and California's Central Valley is Lawrence Livermore's Experimental Test Site. It has been known as Site 300 since the days when Livermore was part of Berkeley Radiation Laboratory: Berkeley was Site 1, Livermore was Site 2, and the testing range was Site 3. Times and names have changed, but the periodic BOOMS continue.

The explosions, known as shots, result from destructive tests of high explosives (HE) and other nonnuclear weapon components—100 to 200 of them a year in the last 10 years. Powerful x-ray machines, interferometers, high-speed cameras, and other diagnostic equipment record information about the experiment in the first nanoseconds after detonation. Site 300 also conducts nondestructive tests that may, for example, subject a prototype to vibration and extreme heat, conditions comparable to those it might encounter while being transported across a desert. Another big part of Site 300's work is fabricating and machining HE and assembling experiment devices prior to testing. All of these activities are potentially hazardous, yet Site 300 has a stellar safety record. In 44 years, no injuries involving high explosives have occurred.

Figure 1. Vehicles and personnel entering Site 300's firing area must pass the central control point, where Art Caya accounts for arrivals and departures.



Much of Site 300's effort supports Lawrence Livermore's main mission today of overseeing the nation's nuclear arsenal through the Department of Energy's science-based Stockpile Stewardship Program. As part of the program, the Accelerated Strategic Computing Initiative (ASCI) is bringing almost unimaginable power to Livermore's modeling capability to simulate weapons performance. And in a few years, the National Ignition Facility will be available for addressing the physics of thermonuclear fusion. Yet, even with these unprecedented capabilities at Livermore, tests at Site 300 are perhaps more important now than ever before.

HE testing, using nonnuclear materials, is almost the only available high-fidelity way of experimentally

examining the operation of a nuclear weapon. The U.S. no longer conducts nuclear tests, and only a few subcritical (no nuclear yield) experiments are being conducted at the Nevada Test Site. The high-explosives tests are also important for improving our understanding of the effects that aging has on chemical high explosives in stockpile systems and of compatibility with other materials. Validation of models and simulations through actual experiments are essential for scientists to know whether their design is, figuratively speaking, on target.

Testing More Parameters

According to Randy Simpson, a chemist and HE expert at Livermore, "We understand the stars and supernovae better than we understand high explosives. When high explosives

detonate, they can generate up to 500,000 atmospheres of pressure and may move at speeds of up to 10 kilometers per second. Reactions take place in less than a billionth of a second, releasing enormous amounts of energy. Our Site 300 experiments study how high explosives release their energy—for example, how they accelerate metals or what chemical reactions they cause."

The tests allow us to study the performance of HE materials, their reliability and safety, and ways to optimize the materials and manufacturing methods. Three avenues of testing ensure the HE portion of stockpile performance: core surveillance testing of operational weapon HE function, enhanced surveillance to test the effects of aging on HE, and testing of replacement and specialized HE components.

Protecting the Environment

Not bothered by the occasional noise, a healthy wildlife population runs over the hills and ravines of Site 300. Three endangered species—the San Joaquin kit fox, the red-legged frog, and the large-flowered fiddleneck plant—are afforded special protection. Site 300 is also a friendly spot for birds of prey, which use high-voltage power lines for perching because of the lack of trees. Laboratory staff have outfitted power poles with antielectrocution sleeves to protect the birds. Site 300's full-time wildlife biologist helped to invent the tiny MOLE, a remotely controlled robot (photo at right) that explores and observes certain sensitive species in their dens.

Past activities at Site 300 have contaminated some soil and groundwater, which are being treated in a variety of ways. For example, trichloroethylene (TCE), a toxic carcinogen and solvent, was used for many years in the environmental test area as a heat exchange fluid for thermal testing. An environmental restoration program is extracting groundwater and soil vapor from the subsurface to remove the contaminants.

Several "green" restoration technologies—which use less energy and have less impact on the environment than many conventional cleanup methods—are also being implemented at Site 300. "It makes sense to clean up the environment using techniques that are kind to the environment," notes environmental

scientist John Ziagos, who is responsible for restoration work at Site 300. A geosyphon, which sucks water out of the ground by discharging elsewhere, is planned for a testing area. Electricity is needed only to get the pump started. Then gravity takes over and pulls water out for treatment. A system known as SWAT (solar-powered, water-activated-charcoal treatment) is being considered for remote parts of the site where no power lines run. Microbial methods and wind-powered treatment are also likely to be employed in the next year or so.



For as long as the U.S. has had a nuclear stockpile, personnel at Site 300 have been participating in core surveillance of the stockpile. Periodically, weapons have been taken apart and components put through their paces to ensure that everything is still operating as designed.

Now that weapons are being kept in the stockpile beyond their design lifetimes, a part of the Stockpile Stewardship Program known as enhanced surveillance uses experiments and modeling to predict what changes are likely to occur over time and their possible impact on safety or reliability. Enhanced surveillance is central to meeting the defense objectives of the U.S. and its allies in this era of no nuclear testing.

One series of enhanced surveillance tests at Site 300 compared the performance of new and aged explosives. According to Jon Maienschein, the

Livermore chemical engineer who oversees the enhanced surveillance work with explosives, "The good news is that our high explosives are not degrading much, but that also makes predicting changes more difficult."

One difficulty in studying aged high explosives is that they are hard to obtain. The oldest are only about 25 years old, yet the enhanced surveillance program seeks to project changes 50 years from now. So scientists at Livermore's High Explosives Applications Facility (HEAF) are working to formulate substances that simulate high explosives of various ages. HEAF is permitted to manufacture up to 100 grams of high explosives, while larger amounts must be manufactured at Site 300. Maienschein anticipates that the simulated aging effort will reach the point sometime in the next year, when larger-scale HE manufacturing and additional testing can begin.

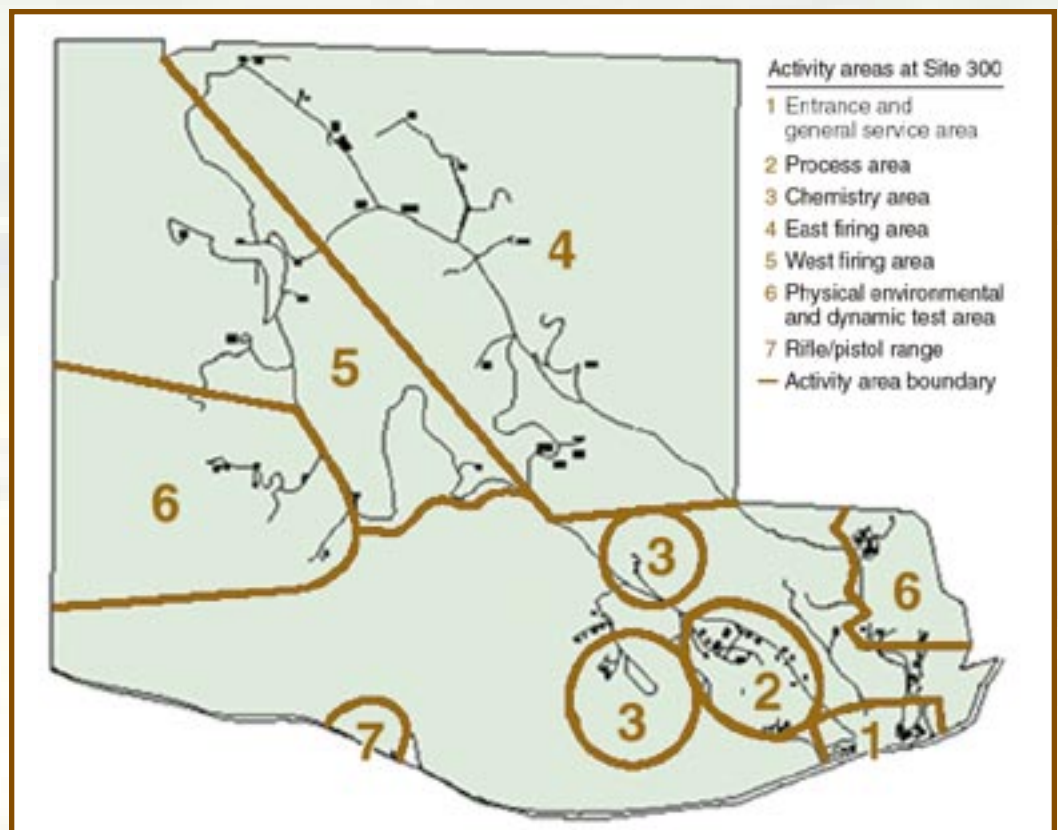
As parts and materials in weapons age, they must be replaced. Replacement is more complicated than it once was because most nuclear weapons manufacturing facilities have shut down, and environmental requirements have changed. As new manufacturing processes are devised and new nonnuclear parts are fabricated, many explosives find their way to Site 300 for testing before they are installed in weapons.

For decades, Site 300 has also tested Livermore-designed conventional weapons, such as shaped charges, which have been deployed by the Department of Defense in specialized armaments. These conventional weapons contain high explosives whose behavior and effects on other weapon materials must be tested and compared to modeled predictions.

A Quick Tour

Site 300 is set on 7,000 acres of land about 15 miles east of Livermore. It is

Figure 2. Activity area map of Site 300.



marked by both rolling hills and steep ravines with very few trees in sight aside from those planted around the parking lots and administrative buildings near the entrance. When it was established in 1955, Site 300 was a very remote area surrounded only by cattle ranches. It is still remote, but these days the city of Tracy is expanding toward the site from the east.

As shown in **Figure 2**, several administrative and service buildings are clustered near the entrance to the site where site manager Milt Grissom and others have their offices. The environmental test area is to the northeast. The area where high explosives are fabricated and test

devices are assembled is to the north (areas 2 and 3 on the map). The firing bunkers, where high explosives and other weapon components are detonated on open firing tables, are still farther north, separated from each other and well away from the boundaries of the site. Scattered throughout the site are earth-covered magazines for storage of high explosives, waste collection and treatment areas, and numerous storage buildings.

Set on a knoll looking east and south is Site 300's weather station. It gathers weather information before each shot and helps Site 300 to be a good neighbor by not exceeding a self-imposed noise threshold. Two to three hours prior to a

shot, a weather balloon is released with a sonde attached. The sonde collects temperature data during its ascent through the atmosphere and transmits the information back to the weather station. At the same time, radar tracks the balloon and collects wind velocity data. This information is used in a computer code to predict the maximum amount of high explosives that can be detonated without exceeding the Laboratory's noise limit of 126 decibels for populated areas. If the data indicate that a populated area will be "popped," the test is postponed until weather conditions are more favorable.

"All of our facilities are staffed by 48 highly skilled technicians," notes

Countdown to a Shot

The explosion may be what you hear, but weeks and sometimes months of effort by many people go into making the shot perform as planned. A scientist at Livermore will have the original concept for an experiment. The scientist then needs engineers to turn the physics design into a manufacturable engineering design.

Technicians in Livermore's engineering shops build most of the parts, except for the high explosives, which are manufactured at Site 300. Technicians at the high-explosives process area assemble the whole package, sometimes including a pin dome (**Figure 6**) and other devices needed for gathering information about the experiment.

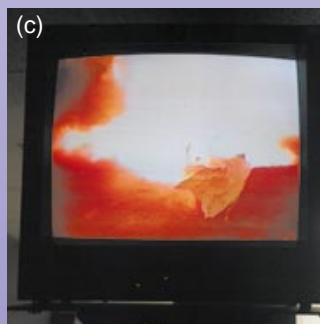
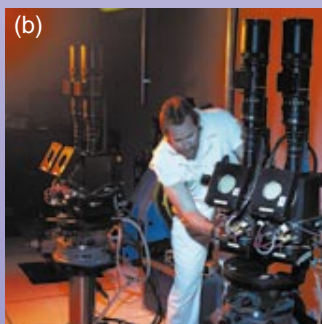
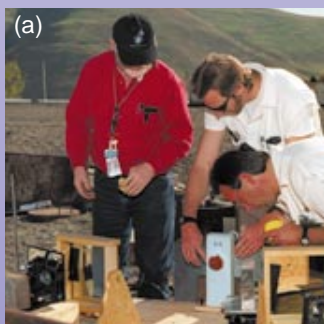
The test assembly is moved to either Bunker 801 or 851, and all diagnostic equipment is set up. Electronic timing devices are set to synchronize all equipment for the experiment.

A weather balloon is sent up to assure that shot noise will not exceed 126 decibels in populated areas. The Stockton Airport is notified so that it can keep aircraft out of Site 300's air space.

The bunker supervisor calls a muster, and every person who has signed in at the bunker must be accounted for. There is a final dry run, and last-minute adjustments are made. Someone goes to an observation point to assure that no unauthorized personnel enter the danger area by vehicle or aircraft. If there are, the shot is postponed.

After the console operator pushes the "FIRE" button, several things still must happen in the microseconds before and after detonation begins. The cameras are automatically synchronized, laser-pulsed flashlamps light up the shot for the cameras, the laser for the interferometer is pulsed, and the radiography system is pulsed.

Finally, weeks after work first started on the shot, the test assembly, so carefully constructed, is blown to smithereens while diagnostic equipment records the first moments after detonation. Then scientists back in Livermore evaluate the data and begin work on another test.



Setup activities for a shot (a) at the firing table and (b) in the high-speed camera room. (c) Video playback of a shot is just one of many diagnostics.

site manager Grissom. “The experiments we perform are expensive, so the techs have to get it right the first time. And they do, consistently.” After years of employment, they have specialized knowledge about machining high explosives, operating environmental test equipment, or setting up the flash x ray for a hydrodynamic test. With no vocational or college major education in HE and testing, virtually all technicians have been trained on the job. Jack Lowry, supervisor of one of the firing bunkers, was a miner early in his career and learned about explosives then. Chuck Cook, who operates radiography equipment at the bunkers, was a hospital x-ray technician. They and others brought

relevant experience with them when they started working on HE tests, but they still had much to learn about this unique field.

Fabricating Explosives

Research and development of high explosives for various applications take place at HEAF in Livermore (*S&TR*, June 1997, pp. 4–13). Notes A. J. Boegel, manager of Site 300’s high-explosives process area, “The 100 grams of high explosives that HEAF can manufacture and 10 kilograms that HEAF can test are sufficient for laboratory-scale experimental purposes but not enough for full-scale testing.”

Starting with HEAF’s small recipe, technicians at Site 300 begin to scale up

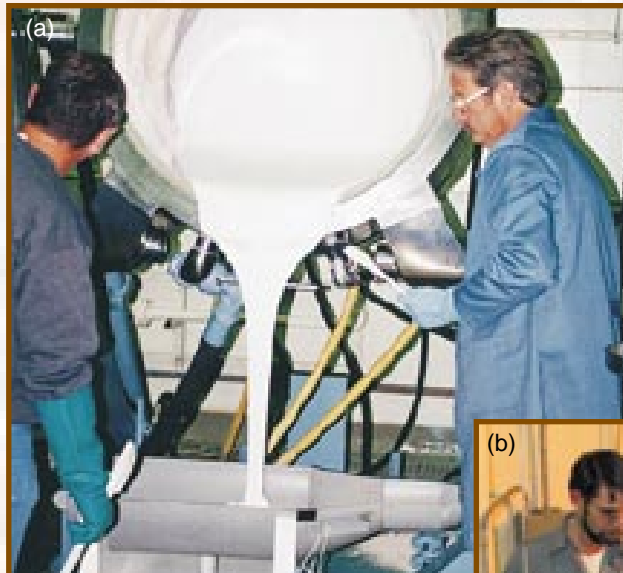
the formulation. Any cook knows that doubling or tripling a recipe is not always a simple linear process of doubling or tripling all ingredients. The end product may be too salty or there may be other problems. The same is true for HE formulations, but the results of errors are potentially much more serious than a too-salty cake. Scaling up takes place gradually, with samples tested frequently.

Site 300 personnel also manufacture the HE routinely used in tests and prepare new formulations for specific applications. In a recent project, a special formulation was developed at HEAF and manufactured at Site 300 for the Department of Defense. Site 300 also manufactured substances that have been used to train dogs to sniff out HE.

A pilot-scale plant at Site 300 is used to test a new way to synthesize TATB, an HE with such low sensitivity, that it is the safest high explosive available. But conventional manufacturing methods are expensive, and HEAF scientists have developed better methods.

Paste high explosives are used in shaped charges. They are extruded into the shaped-charge cavity, so they require no machining. Plasticized high explosives require a different process.

Figure 3. Ready high explosives for a test. (a) Mark Hoffman and Kirk Pederson mix HE, (b) Dean Adams and Monty Sappenfield remove an HE component from a presser, and (c) Aniceto Salmon machines a component to final tolerances.



First, they are manufactured into a powder, which is heated to soften the plastic binder. The heated mixture is then pressed into the shape needed for a particular experiment, x-rayed for cracks, machined, and inspected mechanically to test for tolerances (Figure 3). With both paste and plasticized high explosives, two units are often made: one is subjected to environmental tests to assure its safety before the other one is used in the planned shot.

All of this work—mixing, extruding, heating, pressing, and machining, whether for new or standard formulations—is done remotely. Thick concrete walls and earth berms separate the control rooms from these operations. Cameras and microphones trained on the work are the technician's eyes and ears, and redundant control systems provide additional safety. The work bays are buried in earth on one side with a blowout wall on the other side to release energy should an accident occur.

The final operation in this area—device assembly—cannot be done remotely. Some devices have more than 100 parts, and assembly can take two weeks to complete. The process must meet very

tight tolerances if modeling codes and performance criteria are to be validated.

Shake, Rattle, and Roll

At the environmental test area, Ron Samoian directs safety characterization tests. Several facilities subject prototype high explosives, detonators, and other energetic materials as well as nonnuclear stockpile components to vibration, shock, impact, acceleration, twisting, and various combinations of heat and cold. Some tests simulate accidents, from dropping explosives to aircraft crashes and fuel fires. The test units can be subjected to vibration levels that encompass both ground and aircraft transportation over temperatures ranging from arctic to desert conditions. Some tests, such as a fall in the 30-meter drop tower (Figure 5a and b), are over in a few seconds. Other tests to study how materials age under various conditions have run for years.

All testing is done remotely with cameras, microphones, and electronic sensors reporting to a central control room. Testing bays are constructed like the ones in the high-explosives process area with a heavy earth berm behind a blowout wall and roof (Figure 4).

Vibration and shock testing can be done in any of three shakers. One of the electrodynamic shakers (Figure 5c) can reach 40,000 pounds of force with a 1-inch stroke. The hydraulic shaker goes to 60,000 pounds of force with a 6-inch stroke. All the shakers can be flipped 90 degrees so that testing can be done side to side as well as up and down. Frames for shock testing allow drops of 20 centimeters to 30 meters. Impulse testing is done using a gas-operated piston to accelerate a specimen into a specially designed target. Torsional testing is done at a table where samples are subjected to quick twisting (Figure 5).

All of these tests can be combined with thermal conditioning. High-explosive samples may be heated electrically to 73°C or cooled using liquid nitrogen to -73°C. A sample being dropped from the 30-meter drop tower must be thermally conditioned first. Thermal chambers fit over the shakers and smaller drop frames for simultaneous thermal conditioning.

Recent work has included testing of high-explosive components of the W87 nuclear weapon, which was designed at Livermore. When the weapon was first



Figure 4. The environmental test area at Site 300 includes a testing bay protected by an earth berm (at left).

developed, the high explosives in it were subjected to the full range of vibration, shock, and temperature testing, which established an “envelope” of safe responses. The testing that is done as the weapon and its components age determines how the collection of responses has changed and whether those changes affect weapon safety.

Fire Away!

The two main firing bunkers, 801 and 851, come under the management of Kent Haslam. Bunker 801 is now used primarily for tests related to nuclear weapons. Bunker 851 is

generally used for testing conventional weapons such as shaped charges.

Back in 1955, the only diagnostic technique available for studying a shot was high-speed photography, and it was not possible to synchronize multiple cameras. More sophisticated versions of the same cameras are used today, along with radiography for recording the inside of thick metal parts and interferometry for measuring velocities of explosion-driven surfaces. Another often-used diagnostic is the pin dome (Figure 6). Its many fiber-optic wires electronically record the velocity and symmetry of an implosion. Today, a timing system

synchronizes all of the diagnostic tools with the detonation.

Bunker 851 supervisor Jack Lowry notes, “There used to be lots of experiments with fewer diagnostics. Now each shot has lots of diagnostics. Computers make the difference, allowing us to gather huge amounts of information. And we at Site 300 and the scientists at Livermore are constantly trying to figure out ways to get more data.”

High explosives produce pressures so high that solid materials, even when not melted, flow like fluids (Figure 7). Many of Site 300’s shots are designed to study this hydrodynamic behavior

Figure 5. (a) The 30-meter drop tower in action, (b) an aerial view of the tower, and (c) (left to right) Bill Stigman, Jess Squires, and Bruce Kleg examine a re-entry vehicle after a test on the shaker.



either in conventional weapons or nuclear weapons. For studying the hydrodynamics of a nuclear weapon, a nonfissile material is wrapped in a high explosive with the same geometry as the core of a weapon. This mockup is detonated, resulting in an explosive compression that deforms the material, making it denser and causing it to flow. With “hydrotests,” scientists seek to better understand this complicated behavior, whose physics are still not well understood.

The first hydrodynamics test facility at Site 300 was Bunker 801. Originally a Quonset hut, Bunker 801 now is a state-of-the-art testing facility housing the Flash X-Ray (FXR) machine, a linear induction accelerator specifically designed for diagnosing hydrotests by radiographing the interior of an imploding high-explosive device. Its x rays are so powerful that they can penetrate more than a foot of steel and record the motion of materials moving at ultrahigh speeds. Says Doug Bakker, supervisor of Bunker 801, “The typical shot using the FXR is a hydrotest for a mockup nuclear weapon assembly. Because of the high densities of the materials used in these assemblies, only the FXR can do the job.”

Already the world’s most sophisticated flash x-ray system, the FXR has recently been upgraded so that two x rays may be obtained during a single test. A gamma-ray camera system, designed by Livermore scientists and 70 times more sensitive than radiographic film, records the picture produced by the FXR’s x rays (see *S&TR*, May 1997, pp. 15–17).

In April 1999, construction of the Contained Firing Facility (*S&TR*, March 1997, pp. 4–9) is scheduled to begin at Bunker 801 to provide a controlled environment for high-explosives testing (Figure 8). When construction is complete sometime in late 2001 or early 2002, Bunker 801 will also incorporate a multibeam Fabry–Perot interferometer to provide as many as 20 data collection

points for measuring surface velocities during an experiment (*S&TR*, July 1996, pp. 12–19).

While Bunker 801 is out of commission during construction, most experiments will be moved to Bunker 851. Particularly large tests will be sent to the Nevada Test Site.

Diagnostic equipment at Bunker 851 is similar to that at 801, except that its radiographic equipment produces a lower dose of radiation than the FXR. Thus, Bunker 851’s accelerator is effective in radiographing less dense materials. The bunker also houses portable x-ray equipment and a 15-beam

Fabry–Perot interferometer, which is being upgraded to 20 beams.

The tests of aged high explosives for the enhanced surveillance program were run at Bunker 851. Another recent series of tests studied shaped charges for use in counterterrorism. Technicians recently ran a series of tests of shaped charges for an oil company, which uses them as perforators to open oil-bearing rock.

A Bright Future Ahead

“Site 300 is busier now than it’s ever been in my nine years here,” says site manager Milt Grissom. “Not only are we running experiments at our own bunkers,

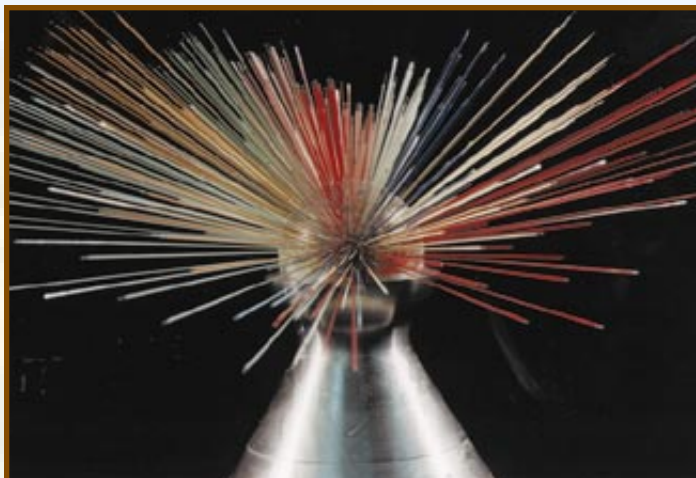


Figure 6. The fiber-optic “pins” on this pin dome receive velocity and symmetry information while a test device implodes.

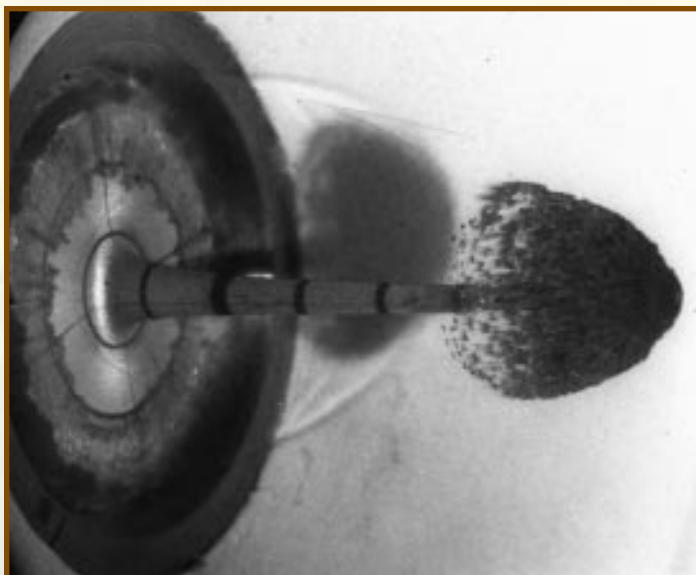


Figure 7. A shaped charge speeds to the right at 8 kilometers per second during a hydrodynamic test, which illustrates the fluid-like behavior of metals when they are subjected to extremely high pressures.

but our technicians are also working on experiments at the Nevada Test Site. They are manufacturing the high explosives and then going to Nevada to set up the experiments and run the diagnostics. On top of that, construction of the Contained Firing Facility will start soon, and we are getting more and more work.

"Our infrastructure has to support all of this activity," he continues. Construction will begin soon on a combination fire house, medical facility, and badge office near the entrance to the site. Administrative staff have outgrown available space and so will move into the old fire house.

Grissom goes on, "With over 200 people that work here representing so many areas of the Laboratory, my job ought to be tough. But it isn't at all. There's a great can-do attitude here." That attitude will stand Site 300 in good stead as it continues its busy schedule.

—Katie Walter

Key Words: enhanced surveillance, environmental restoration, Fabry-Perot interferometer, Flash X-Ray (FXR) machine, high explosives, High Explosives Application Facility (HEAF), hydrodynamic tests, MOLE, shaped charges, Site 300, stockpile stewardship.

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Figure 8. Bunker 801 as it will look when the Contained Firing Facility is complete.

About the Engineer



MILTON L. GRISSOM has been manager of Livermore's Experimental Test Site (Site 300) since 1990. During his 33-year career at the Laboratory, Grissom has held numerous technical and administrative leadership positions, including leading many projects within the Mechanical Engineering Department's Nuclear Explosives Engineering Division. He currently serves as a Laboratory Emergency Duty Officer (LEDO) and is chair for the Laboratory's Operational Security Program and Work

Smart Standards committee.

Grissom holds a B.S. in mechanical engineering from the University of New Mexico and an M.S. in mechanical engineering from San Jose State University.